

NASA
National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attention GP

FEB 28 1978

TO: NHB/Scientific & Technical Information Office

FROM: GP-4/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP-4 and Code NHB, the enclosed NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,543,839

Government or TRW, Inc.
Corporate Employee : Redondo Beach, CA

Supplementary Corporate
Source (if applicable) :

NASA Patent Case No. : ARC-10,199

NOTE - Is this an invention made by a corporate employee
of a NASA contractor? YES ☒ NO ☐

If "YES" is checked, the following is applicable: Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Elizabeth A. Carter/*SA*

Enclosure



(NASA-Case-ARC-10199) MULTI-CHAMBER
CONTROLLABLE HEAT PIPE Patent (NASA) 8 p
CSCL 20D

N78-17337

Unclas

00/34 05411

United States Patent

W-1047
ARC-10,199-1
[11] 3,543,839

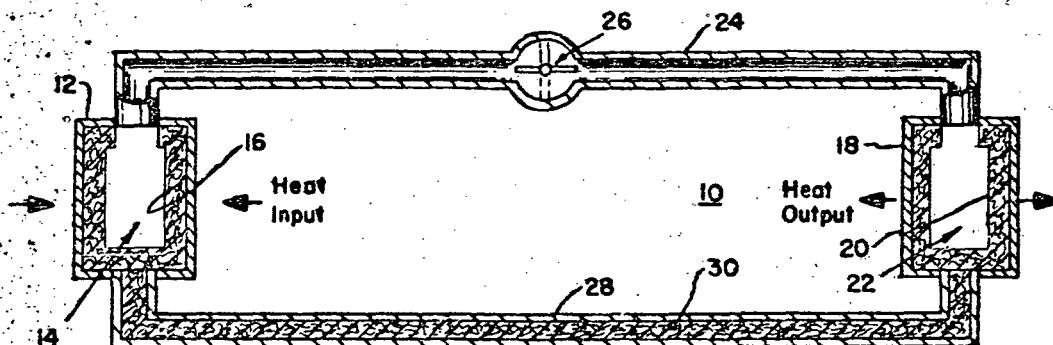
[72] Inventor Arnold P. Shlosinger
Los Angeles, California
[21] Appl. No. 824,628
[22] Filed May 14, 1969
[45] Patented Dec. 1, 1970
[73] Assignee TRW, Inc.
Redondo Beach, California
a corporation of Ohio

[56] References Cited
UNITED STATES PATENTS
3,404,730 10/1968 Kurisu..... 165/105X
3,414,050 12/1968 Anand..... 165/105X
Primary Examiner—Albert W. Davis, Jr.
Attorneys—Daniel T. Anderson, Jerry A. Dinardo and Donald
R. Nyhagen

[54] MULTI-CHAMBER CONTROLLABLE HEAT PIPE
15 Claims, 5 Drawing Figs.

[52] U.S. Cl. 165/32;
2/2.1; 165/96, 165/105
[51] Int. Cl. F28d 15/00;
B63c 11/04
[50] Field of Search 165/32, 96,
105; 128/379, 1; 2/2.1

ABSTRACT: A temperature controllable heat pipe switching device includes separate evaporating and condensing chambers interconnected by separate vapor flow and liquid return conduits. The vapor flow conduit can be opened or closed to the flow of vapor, whereas the liquid return conduit blocks vapor flow at all times. When the vapor flow path is open, the device has high thermal conductivity, and when the vapor flow path is blocked the device has low thermal conductivity.



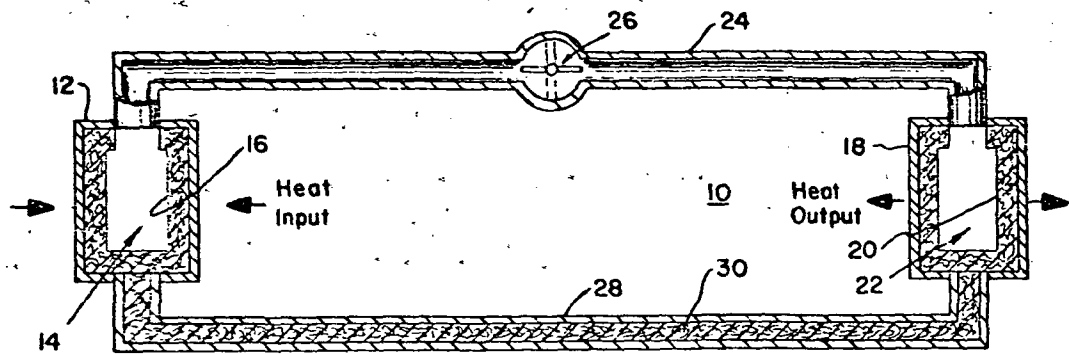


Fig. 1

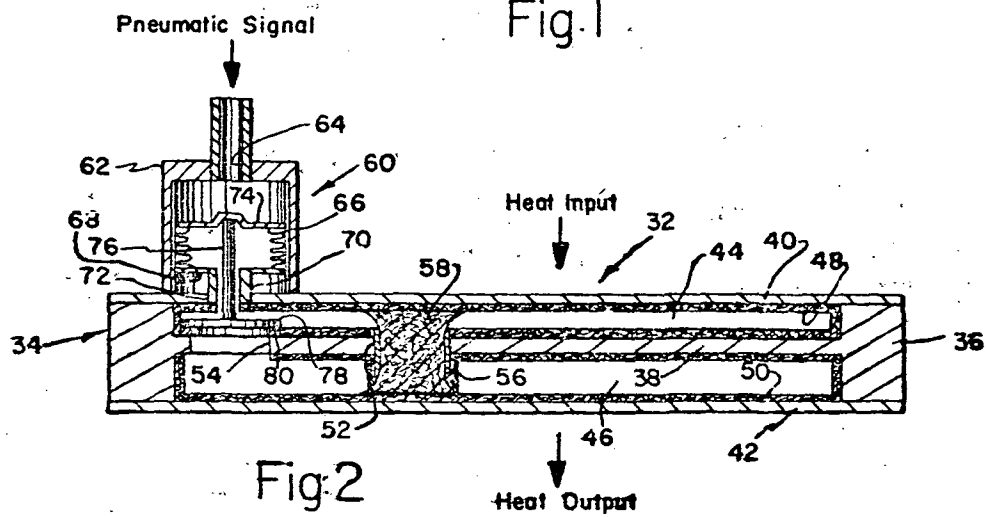


Fig. 2

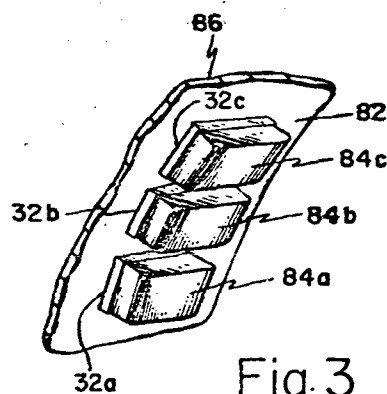


Fig. 3

Arnold P. Shlosinger
INVENTOR

BY *Jerry A. Dinardo*

AGENT

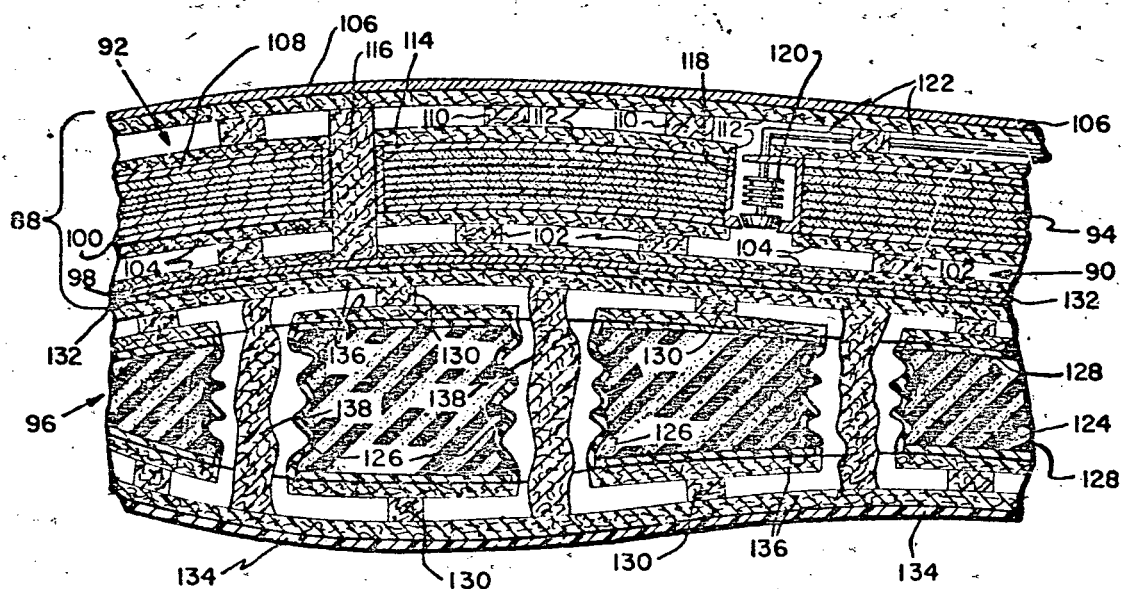


Fig 5

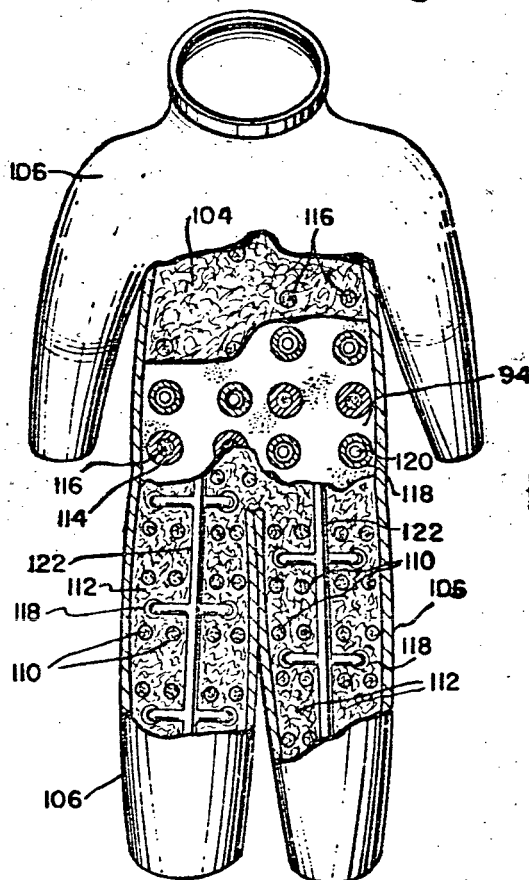


Fig. 4

Arnold P Shlosinger
INVENTOR

BY *Jerry A. Dinardo*

AGENT

MULTI-CHAMBER CONTROLLABLE HEAT PIPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

Heat pipes or heat pipe-type devices operate on closed evaporating-condensing cycles for transporting heat from a locale of heat generation to a locale of heat rejection, using a capillary structure or wick for return of the condensate. Such devices generally consist of a closed container which may be of any shape or geometry. Early forms of these devices had the shape of a pipe or tube closed on both ends and the term "heat pipe" was derived from such devices. The term "heat pipe" as used herein, however, refers to a device of any type of geometry designed to function as described above.

2. Description of the Prior Art

In such a heat pipe device, air or other noncondensable gases are removed from the internal cavity of the container. All interior surfaces are lined with a capillary structure, such as a wick. The wick is soaked with a fluid which will be in the liquid phase at the normal working temperature of the device. The free space of the cavity then contains only the vapor of the fluid, at a pressure corresponding to the saturation pressure of the working fluid at the temperature of the device. If at any location, heat is added to the container, the resulting temperature rise will increase the vapor pressure of the working fluid, and evaporation of liquid will take place. The vapor that is formed, being at a higher pressure, will flow towards the colder regions of the container cavity and will condense on the cooler surfaces of the wick on the inside of the container wall. Capillary effects will return the liquid condensate to the areas of heat addition. Because the heat of evaporation is absorbed by the phase change from liquid to vapor and released when condensation of the vapor takes place, large amounts of heat can be transported with very small temperature gradients from areas of heat addition to areas of heat removal. All the foregoing is well-known, and heat pipes have been recognized for several years as very effective heat transport devices. They will transport large amounts of heat with small temperature gradients independent of gravity effects, which makes these devices suitable for applications in space.

SUMMARY OF THE INVENTION

This invention deals with a modification of the basic heat pipe. This modification permits transfer of large amounts of heat across a relatively small cross section from a heat input surface of large area to a heat rejection surface of large area. According to one embodiment, a relatively large, flat surface, which is used as a mounting plate for electronic equipment whose temperature is to be controlled, constitutes the face of a hollow panel forming one chamber of a two-chamber heat pipe. This first chamber is connected by two, small cross section tubular conduits with another hollow, flat panel of extended surface area. The second panel forms a second heat pipe chamber. One of the connecting conduits serves to transfer the vapor of the working fluid from the first or heat input chamber to the second or heat rejection chamber. The internal surfaces of both chambers are lined with a capillary structure such as a wick and the two wicks are interconnected by a wick completely filling the cross section of the second conduit. The device operates in a manner similar to a single chamber heat pipe, with the difference that the vapor passage and the wick-filled condensate passage are separated from each other, and that instead of one essentially open cavity of a container, two relatively large containers are interconnected by two small cross section conduits. An arrangement of this type has practical value for application to temperature control of spacecraft equipment. In modified forms it serves other useful purposes.

The separation of the vapor conduit and the wick-filled condensate return conduit provides a means for controlling the rate of heat transferred from the heat input to the heat rejection chamber by control of the vapor flow in the vapor conduit. In order to accomplish that, it is necessary to install the

wick in the wick conduit with a snug fit. When this is done, the liquid-soaked wick will not permit passage of vapor and the vapor will be forced to flow only through the vapor conduit. A valve is placed in the vapor conduit to provide control of heat flow from the heat input chamber to the heat rejection chamber. Complete closing of the valve will effectively interfere with heat transfer from the heat input to the heat rejection chamber. Heat transport in a heat pipe is dependent upon vapor mass transfer. If this mass transfer of vapor is stopped, heat pipe action will also stop. Throttling of the valve will result in a pressure differential between the heat input and the heat rejection chamber. Since the temperature in the two chambers is the temperature at which evaporation and condensation takes place, and since these temperatures are functions of pressure, throttling of the valve will result in increased temperature difference between the two chambers and thereby permit temperature control of the equipment located at the heat input chamber.

One advantage of the arrangement of two separate chambers and two separate fluid flow conduits lies in the fact that these conduits can be of relatively small cross-sectional area and can be built of materials of relatively low thermal conductivity such as, for example, fiberglass or plastics. Therefore, the heat leak with the vapor transfer valve in the closed position will be very small. Because of the high effectiveness of heat pipe devices of transporting heat with very small temperature gradient, the heat flow rate achievable with the vapor transport valve open will be very large. Accordingly, this arrangement provides a highly effective heat flow switching device which can be applied to the control of the temperature of electronic equipment on board of spacecraft. The device has other possible applications. For example, the device may be used to bypass a thermal insulating layer between the skin of an astronaut in a space suit and the external surface of such a space suit that functions as a thermal radiator during extravehicular activities.

Other applications of this useful device are foreseeable. The need for thermal switching devices on spacecraft has been recognized for a long time. Devices serving the same purpose have been applied to a number of operational unmanned spacecraft. The design of the electronic equipment temperature system on the surveyor spacecraft used a thermal switching device consisting of plates which, by an automatic control system, were either contacting each other or taken out of contact. Because of the relatively low thermal conductivity and the difficulties in predictability and repeatability of the heat transfer across contacting surfaces, this device had severe limitations in heat transport rate. Other spacecraft, including the Mars and the Venus Mariner vehicles had a requirement for variation of heat rejection from their electronic devices because their trajectories brought the spacecraft either closer, in the case of Venus, or further away, in the case of Mars, from the sun, which resulted in a significant change of the energy received by these vehicles by solar radiation. Shutters over the thermal radiators of the Mariner vehicle, which effectively changed the ratio of heat absorption to heat rejection were used. Such shutters are extremely sensitive devices and the variations obtainable are limited. The device described herein is simpler, more reliable and more efficient in heat transfer than devices so far used.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a heat pipe device functioning as a thermal switch according to the invention;

FIG. 2 is a cross-sectional view of a thermal switch in panel form;

FIG. 3 is a fragmentary perspective view of a spacecraft incorporating thermal switches for cooling electronic equipment;

FIG. 4 is a plan view of a space suit incorporating variable thermal conductance means according to the invention; and

FIG. 5 is a sectional view of a portion of the space suit of FIG. 4 in combination with an undergarment to be worn by an astronaut.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown in diagrammatic form a heat pipe device 10 which functions as a thermal switch in the sense that heat flow is controlled by controlling the flow of vapor. The heat pipe device 10 includes a first enclosure 12, the interior of which defines an evaporating chamber 14. The interior walls of the evaporating chamber 14 are lined with capillary material or a wick 16.

A second enclosure 18 spaced from the first enclosure 12 and similar thereto has its interior walls also lined with a wick 20 forming a condensing chamber 22.

A first conduit 24 is connected between the two enclosures 12 and 18 at upper portions thereof to provide a first path of communication between the two chambers 14 and 22. A valve 26 provided in the first conduit 24 is operable to open or close the flow of working fluid vapor between the two chambers 14 and 22.

A second conduit 28 is connected between the two enclosures 12 and 18 at lower portions thereof to provide a second path of communication between the two chambers 14 and 22. The second conduit 28 is filled with a wick 30 connecting the wicks 16 and 20 of the two chambers 14 and 22 respectively. The relative positions of the conduits 24 and 28 may of course be reversed. A sufficient quantity of working fluid is provided to saturate the wicks 16, 20 and 30. A working fluid is selected that will be in the liquid phase at the lowest desired temperature of operation and has a thermodynamic critical temperature well above the highest temperature of operation anticipated.

In order for the heat pipe device 10 to function as a means for transferring heat from the evaporating chamber 14 to the condensing chamber 22, the control valve 26 is placed in the open position, as illustrated in solid lines. The application of heat to the evaporating chamber 14 will cause the working fluid vapor to flow through the first conduit 24 into the condensing chamber 22. Because the second conduit 28 is filled with a wick 30 that is saturated with working fluid liquid, no vapor flow can take place through the second conduit 28. Vapor flow will occur only through the first conduit 24 when the control valve 26 is open. The vapor condenses in the condensing chamber 22 where it gives up its latent heat of vaporization to the walls of the condensing chamber 22. The walls of the condensing chamber 22 in turn radiate this transported heat to its surroundings. The condensed liquid returns to the evaporating chamber 14 through the second or wick filled conduit 28.

It is thus seen that the device 10 is provided with separate evaporating and condensing chambers 14 and 22 respectively, and that these chambers are connected by separate vapor and liquid flow paths. Vapor flow can occur only through the first or vapor flow conduit 24, and liquid return flow can occur only through the second or liquid flow conduit 28.

When it is desired to cut off heat pipe action, or to stop the transport of heat between the evaporating chamber 14 and the condensing chamber 22, the control valve 26 is placed in the closed position, as indicated in phantom. The flow of vapor is blocked in the vapor flow conduit 24. A pressure differential is established between the two chambers 14 and 22, the pressure being higher in the evaporating chamber 14. Since the temperature in the chambers 14 and 22 is a function of pressure, the temperature will build up in the evaporating chamber 14 and there will be a temperature gradient between the two chambers 14 and 22. There is no way to transport the excess of heat from the evaporating chamber 14 to the condensing chamber 22 because there is no way for the vapor to flow between the two chambers 14 and 22.

With the flow of vapor blocked off in the vapor flow conduit 24, the pressure in the evaporating chamber 14 eventually

builds up to the point where it drives the working fluid liquid out of the wick 16 in the evaporating chamber 14 and through wick 30 into the condensing chamber 22. The removal of working fluid from the evaporating chamber 14 hastens or contributes to the stoppage of heat flow.

When it is desired to resume heat pipe action, the control valve 26 is opened to equalize the pressure in both chambers 14 and 22. The working fluid is pumped back into the evaporating chamber 14 through capillary action in the wicks 30 and 16. Evaporation of the working fluid in the evaporating chamber 14 resumes along with transport of the vapor through the vapor flow conduit 24 and condensation of the working fluid vapor in the condensing chamber 22, followed by capillary return of the condensate to the evaporating chamber 14.

It is now apparent that the heat pipe device 10 functions as a thermal switch whereby the flow of heat between the evaporating and condensing chambers 14 and 22 can be controlled by opening or closing the control valve 26.

Referring now to FIG. 2, there will be described a broad area device in the form of a plate or panel which embodies the concept of a thermal switch. The thermal switch 32 comprises a thermal insulating member 34, which may be circular or rectangular in form, and of broad area relative to its thickness. The insulating member 34 includes an outer flange portion 36 and an inner web portion 38. Two thermally conducting plates 40 and 42 are securely mounted on opposite sides of the flange portion 36, as by cementing, so as to form an evaporating chamber 44 bounded by the top plate 40 and the upper side of the web portion 38, and a condensing chamber 46 bounded by the bottom plate 42 and the lower side of the web portion 38.

The walls of the chambers 44 and 46 are lined with adherent wicks 48 and 50 respectively. The web portion 38 is provided with two openings 52 and 54. One of the openings 52 is fitted with a short tube 56 that is filled with a wick 58 interconnecting the other two wicks 48 and 50. The tube 56 and wick 58 constitutes a liquid flow conduit for transporting condensate from the condensing chamber 46 to the evaporating chamber 44. Sufficient working fluid is provided to saturate the wicks 48, 50 and 58.

The other opening 54 in the web portion 38 serves as a vapor flow conduit, which can be opened or closed to control the flow of vapor from the evaporating chamber 44 to the condensing chamber 46. To this end, a pneumatically actuated valve 60 is provided to open or close the opening 54. The valve 60 includes a housing 62 hermetically sealed on the upper plate 40 and provided with an inlet orifice 64 for introducing air under pressure. Within the housing 62 is mounted a resilient bellows 66. The lower end of the bellows 66 is rigidly mounted on an annular plate 68. The annular plate 68 is integrally united with a cylindrical sleeve 70, the lower end of which is sealed in an opening 72 in the upper thermally conducting plate 40. The upper or movable end of the bellows 66 is closed by a diaphragm 74. Depending from the movable diaphragm 74 is a valve stem 76 which extends through the sleeve 70 and into the evaporating chamber 44. The lower end of the valve stem 76 terminates in a valve disk 78. An annular valve seat 80 is mounted on the upper surface of the web portion 38 surrounding the opening 54 between the two chambers 44 and 46. When the valve disk 78 contacts the valve seat 80, it closes the opening 54 between the two chambers 44 and 46.

With no air pressure applied through the orifice 64, the valve disk 78 is retracted from the valve seat 80 by the spring force of the bellows 66 to provide a vapor flow path from the evaporating chamber 44 to the condensing chamber 46 through the opening 54. When air pressure is applied through the orifice 64, the diaphragm 74 is urged towards the annular plate 68, compressing the bellows 66 and moving the valve disk 78 against the valve seat 80, thereby closing the opening 54 and cutting off vapor flow between the two chambers 44 and 46. When the air pressure is removed, the bellows 66 springs back, moving the diaphragm 74 away from the annular

plate 68 and moving the valve disk 78 away from the valve seat 80 to clear the opening 54.

In one operative embodiment, the insulating member 34 was made of acrylic plastic, the thermally conducting plates 40 and 42 were made of copper, and the wicks 48, 50 and 58 were made of quartz fiber cloth. The working fluid was water.

The operation of the thermal switch 32 is similar to that already described in connection with the heat pipe device 10 of FIG. 1. It will suffice to say that in the absence of a pneumatic signal, the opening 54 is unblocked. Accordingly, any heat applied to the outer surface of the upper thermally conducting plate 40 will be transported to the lower conducting plate 42 and, for example, radiated from the latter. When a pneumatic signal is applied to the control valve 60, the vapor flow opening 54 is blocked and heat pipe action is stopped. Stated another way, the thermal resistance between the conducting plates 40 and 42 is high and the flow of heat between the plates is obstructed.

Referring now to FIG. 3, there is shown an application of a thermal switch to control the temperature of electronic equipment aboard a spacecraft such as a satellite.

On the internal skin surface 82 of the spacecraft, a fragmentary portion of which is shown, there are mounted a number of thermal switches 32a, 32b, 32c, similar to the switch 32 of FIG. 2. For example, the conducting plate 42 of FIG. 2 may be mounted on the surface 82. A number of electronic modules 84a, 84b and 84c are mounted on the thermal switches 32a, 32b, 32c. For example, each module may be mounted on a conducting plate 40 of FIG. 2.

The thermal switches 32a, 32b, 32c operate to control the temperature of the electronic modules 84a, 84b, 84c by controlling the thermal energy conducted from the modules to the internal skin surface 82 and then radiated from the external skin surface 86. The thermal switches 32a, 32b, 32c may be actuated by control signals that are derived from sensing the temperature of the electronic modules. The temperature of the modules may be subject to change depending upon the position and distance of the spacecraft from the sun, or radiations in power input, for example. If the temperature of the module tends to increase above a predetermined control temperature, the thermal switches are switched to a high conductivity state to carry away the excess heat. If the temperature of the modules tends to decrease below the control temperature, the thermal switches are switched to a low conductivity state to prevent heat loss from the modules.

Referring now to FIGS. 4 and 5, there is shown a space suit shell 88 incorporating a variable thermal conductance means according to the invention. The variable thermal conductance means can be used to regulate the transmission of heat from the body of an astronaut to the external radiating surface of the space suit according to thermal conditions in the space environment and the activity level of the astronaut. The thermal control means will be illustrated as applied to what is known as a "hard" space suit. FIG. 4 is a plan view of the space suit shell 88 in its entirety, with various layers thereof peeled away, and FIG. 5 is a cross section of a unit area representing about one square foot of the space suit shell 88.

Each unit area of the space suit shell 88, shown in FIG. 5, includes an evaporating chamber 90 spaced from a condensing chamber 92 by thermal insulation 94. Since the space suit shell 88 is preferably of rigid nonflexible construction, it is necessary to provide a soft undergarment 96 of resilient construction which cushions the astronaut's body from the space suit shell 88 so as to permit body expansion resulting from breathing or muscular activities. The undergarment 96 is worn in thermal contact with the inner side of the space suit shell 88, or next to the evaporating chamber 90.

The evaporating chamber 90 is formed by two thermally conducting plates 98 and 100 spaced by a plurality of wick elements 102 which in turn are mutually spaced laterally and longitudinally in two dimensions. The inner surfaces of the plates 90 and 100 are covered with wick lining 104 bonded thereto and to the wick elements 102.

Similarly, the condensing chamber 92 is formed by two thermally conducting plates 106 and 108 spaced by wick elements 110 that are also spaced laterally in two dimensions. The inner surfaces of the plates 106, 108 are covered with wick lining 112 bonded thereto and to the wick elements 110.

The thermal insulation 94 is preferably made up of a plurality of layers of plastic film, such as polyethylene terephthalate, that is metallized on both sides to provide radiation reflective surfaces for insulation. The spaces between the layers also contribute to the insulation qualities.

A first conduit 114, such as a tubular sleeve, extends through the insulation 94 and the conducting plates 100 and 108 on both sides thereof so as to provide communication between the chambers 90 and 92. The conduit 114 is filled with a wick 116 so as to provide the liquid condensate return flow path.

A second conduit 118 extending through the insulation 94 and the conducting plates 100 and 108 supports a pneumatic valve 120 which receives a temperature control signal in the form of gas flowing through a pipe 122. In the absence of gas flow, the valve 120 opens the vapor flow path between the chambers 90 and 92. When a gas pressure signal is applied to the valve 120, it closes an opening in the conduit 118 adjacent to the evaporating chamber 90 and thereby blocks the vapor flow path from the evaporating chamber 90 to the condensing chamber 92.

The portion of the space suit shell 88 described above represents a cross-sectional length of about one foot in either the longitudinal or lateral direction. Thus the same pattern is repeated over the entire shell 88 as in FIG. 4 to provide a multiplicity of conduits 114 and 118 to provide many vapor and liquid flow paths. If desired there may be provided a number of liquid flow conduits 114 for each vapor flow conduit 118.

The flexible, resilient undergarment 96 will now be described in more detail. Essentially, it consists of a maze of heat pipes so that heat may be readily conducted from the body of the astronaut to the evaporator side of the space suit shell 88. The undergarment 96 includes a central layer 124 of soft, resilient, flexible material, such as foam rubber. The foam rubber layer 124 is provided with a multiplicity of holes piercing the entire layer thickness and carrying a corrugated flexible hollow insert 126 made of synthetic rubber, for example.

Both sides of the foam rubber layer 124 carry an adherent plastic laminate 128 covering only the surfaces but not the holes provided with inserts 126. Spaced from each laminate 128 by a plurality of wick elements 130 is another plastic laminate, the latter including a first plastic laminate 132 which contacts the conducting plate 98 of the space suit shell 88, and a second plastic laminate 134 which contacts the body of the astronaut. The internal surfaces of the plastic laminates 128, 132 and 134 are covered with wick linings 136. The wick linings 136 on the outermost plastic laminates 132 and 134 are connected by elongated wicks 138 that extend through the inserts 126. The elongated wicks 138 are smaller in cross-sectional thickness than the diameter of the inserts 126 and are centrally located to provide space for the passage of vapor along the interior of the inserts 126.

The wick elements 130, wick linings 136 and elongated wicks 138 are saturated with a liquid, such as water, methyl alcohol or a refrigerant. Thus, when worn, the undergarment 96 transfers the body heat by heat pipe action to the space suit shell 88. Continuous vapor flow paths are provided throughout the interior spaces of the undergarment 96 and continuous liquid flow paths for return of the condensate are provided between all the wick elements 130, wick linings 136 and elongated wicks 138.

I claim:

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A thermal switching device, comprising:
means forming a first heat pipe chamber including capillary means on the chamber walls;

means forming a second heat pipe chamber spaced therefrom including capillary means on the chamber walls;

a first conduit communicating between said chambers and having capillary means interconnecting the capillary means of said chambers and provided with means permitting liquid flow but not vapor flow between said chambers; and

a second conduit communicating between said chambers and provided with means operable to open said conduit to vapor flow between said chambers or to close said conduit to vapor flow between said chambers, thereby to control said device between high and low thermal conductivity states, respectively.

2. The invention according to claim 1, wherein said heat pipe chambers have substantially broad coextensive surface areas.

3. The invention according to claim 1, wherein said chambers are contiguously separated by a common wall of thermal insulation.

4. The invention according to claim 1, wherein said first conduit has a filling of liquid-saturated capillary means.

5. The invention according to claim 1, wherein said second conduit is provided with valve means to control the vapor flow therein.

6. A temperature controllable heat pipe device, comprising: first heat pipe means provided with a wick and forming an evaporating chamber having an outer face extended area for receiving thermal energy from an external source; second heat pipe means provided with a wick and forming a condensing chamber having an outer face of extended area for removal of thermal energy;

a first conduit communicating between said chambers and filled with a wick that interconnects the wicks in said chambers, whereby when said interconnecting wick is saturated with working fluid in the liquid phase, it blocks the flow of working fluid in the vapor phase between said chambers;

a second conduit communicating between said chambers; and

valve means in said second conduit and operable between an open position to permit working fluid vapor to flow between said chambers and a closed position to prevent working fluid vapor from flowing between said chambers.

7. The invention according to claim 6, wherein said first and second heat pipe means are contiguously joined by a common wall that divides said chambers.

8. The invention according to claim 7, wherein said first and second conduits extend through said common wall at spaced locations thereof.

9. The invention according to claim 7, wherein said common wall is a thermal insulator.

10. The invention according to claim 6, and further including a thermally insulating means disposed between said chambers and through which said conduits extend for communication between said chambers.

11. A thermal switching device, comprising:

a first panel of thermal conducting material;

a second panel of thermal conducting material spaced therefrom;

means formed of thermal insulation material joining said panels hermetically around their peripheries;

a member of thermal insulation material disposed between said panels and forming a common wall that divides the space between said panels into two separate chambers;

first capillary means containing a working fluid and lining the surfaces of said chambers;

means forming a first opening in said thermal insulation member and filled with a second capillary means connected with said first capillary means;

means forming a second opening in said thermal insulation member; and

valve means associated with said second opening and operable to open or close the same to vapor flow paths between said chambers.

12. A space suit, comprising:

a first pair of spaced sheets provided with working fluid-saturated capillary means on their opposing faces and forming a heat pipe evaporating chamber of broad area;

a second pair of spaced sheets provided with working fluid-saturated capillary means on their opposing faces and forming a heat pipe condensing chamber of broad area;

means mounting said first and second pair of sheets in spaced, parallel and thermally insulated relationship;

a multiplicity of uniformly spaced conduits communicating between said chambers and arranged in units, each of which includes a liquid flow conduit and a vapor flow conduit;

capillary means filling said liquid flow conduit to permit liquid flow between said chambers and to block vapor flow therebetween; and

valve means in said vapor flow conduit and operable between an open position to permit vapor flow between said chambers and a closed position to block vapor flow between said chambers.

13. The invention according to claim 12, and further including a plurality of mutually spaced capillary elements within each of said chambers and connecting said capillary means thereof.

14. The invention according to claim 12 wherein said mounting means includes a member of thermal insulation material.

15. In combination:

a space suit and an undergarment for use therewith and thermally coupled thereto;

said space suit comprising:

a first pair of spaced sheets provided with working fluid-saturated capillary means on their opposing faces and forming a heat pipe evaporating chamber of broad area;

a second pair of spaced sheets provided with working fluid-saturated capillary means on their opposing faces and forming a heat pipe condensing chamber of broad area;

means mounting said first and second pair of sheets in spaced, parallel and thermally insulated relationship;

a multiplicity of uniformly spaced conduits communicating between said chambers and arranged in unit, each of which includes a liquid flow conduit and a vapor flow conduit;

capillary means filling said liquid flow conduit to permit liquid flow between said chambers and to block vapor flow therebetween;

valve means in said vapor flow conduit and operable between an open position to permit vapor flow between said chambers and a closed position to block vapor flow between said chambers;

said undergarment comprising a main body portion of soft, flexible, resilient material;

on each side of said main body portion a pair of flexible, plastic sheets mounted in spaced apart parallel relationship forming a closed cavity;

capillary means lining the interior surfaces of each of said plastic sheets;

a working fluid saturating said capillary means;

capillary elements mutually spaced apart and connecting the capillary means of opposing ones of said plastic sheets;

means forming a plurality of spaced apart conduits extending through said main body portion and into each of said cavities;

each of said conduits including an open path for transmitting working fluid vapor between said cavities and a capillary path interconnecting the capillary means of one cavity with the capillary means of the other cavity for transmitting working fluid liquid between said cavities;

said cavities and said conduits thereby forming a plurality of interconnected, resilient, flexible heat pipes for transmitting astronaut body heat from one side of said undergarment to the other side of said undergarment and to said space suit; and

said undergarment also serving to fill the space between the body of an astronaut and the space suit while cushioning the effects of breathing and muscular activity.

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75